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Physician accessibility: an urban case study of pediatric providers

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Abstract

Social disparity in the spatial distribution of healthcare providers in urban areas is a recognized problem. However, efforts to quantify the problem have been hampered by a lack of satisfactory measurements and methods. We revive and enhance a strategy based on provider density, proposed nearly three decades ago. The method avoids the border-crossing problem associated with provider-population ratios, yet reports spatial accessibility in intuitive units that are easily compared across diverse populations and geographies. We find racial and socioeconomic disparities in our case city, Washington, DC, despite a citywide overabundance of primary care providers for children.

Keywords: Primary care; Children; Urban; Spatial accessibility; Social disparity

Introduction

Distance to provider has been recognized as a significant barrier to healthcare access in the US since the 19th century (Hunter et al., 1986; Jarvis, 1851–1852). From that time until the middle 1970s many attempts have been made to measure spatial accessibility to health service locations, identify areas of provider shortage, and reveal social disparities in spatial accessibility in both urban and rural areas (Elesh and Schollaert, 1972; Morrill et al., 1970; Shannon and Alan Dever, 1974; US Public Health Service and Antonio Ciocco, 1954; Wennberg and Gittelsohn, 1973). The issue has been on the national policy agenda since the 1967 Report of the National Advisory Commission on Health Manpower attributed maldistribution of healthcare professionals to their preference for affluent neighborhoods (US National Advisory Commission on Health Manpower, 1967).

From that time work has continued for rural and mixed urban–rural areas, despite a lack of consensus on how to best measure spatial accessibility (Connor et al., 1995; Fortney et al., 2000; Fryer et al., 1999; Goodman et al., 1997; Joseph and Bantock, 1982; Luo and Wang, 2003; Shi et al., 1999). This primarily rural focus was fueled by the recognition that distance is an obvious impediment in sparsely populated areas, and by the well-documented trend of reduced provider-to-population ratios in rural America (Salsberg and Forte, 2002).

Concern about spatial access to healthcare providers in urban areas has not abated (Council on Graduate Medical Education, 1998; Heinrich, 2001; Smedley et al., 2002). However, with few exceptions (Gesler and

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Meade, 1988; McGuirk and Porell, 1984), US cities have not been studied since the middle 1970s. There are probably two reasons for this. First, attention was increasingly focused on the dramatic rise in the cost of care, and the attendant upheaval in healthcare financing and organization. Second, the intuitive spatial indicators used for large rural geographies, described below, are less relevant in congested urban areas.

Ironically, the waning of research on urban spatial accessibility of healthcare providers corresponded with the increasing accessibility of powerful software and hardware necessary for more valid and sophisticated urban studies. This study revisits the subject for a typical major US city by applying commonly available software and data. We discuss and critique some of the concepts and measurement issues, build on a promising conceptual and methodological approach not used since 1975, and report social disparities in spatial access within the case city. Our demonstration concerns primary care providers for children, although the methods are easily adapted for other age groups and healthcare services. The paper's primary contribution is that it proposes a method for measuring and analyzing spatial accessibility to physicians that is easily understood by health policy makers and is particularly useful for congested urban areas.

Background

Terminology and concepts

A diverse and inconsistent terminology is used to describe aspects of healthcare access and barriers. We favor the conceptualization offered by Penchansky and Thomas (1981), who describe and measure access along five dimensions: accessibility, availability, affordability, acceptability and accommodation. The first two relate to location. Accessibility is travel impedance between client and service points, and is usually measured in units of distance or travel time. Availability refers to the number of local service locations from which a client can choose. In urban areas, where choices of similar distance are common, we believe the two dimensions should be combined. We refer to this combined dimension as "spatial accessibility", a term that is gaining some favor in the healthcare geography literature (Khan and Bhardwaj, 1994; Luo, 2004; Luo and Wang, 2003).

Measures of spatial accessibility

Most published measures can be classified into four categories: provider-to-population ratios, distance to nearest provider, average distance to a set of providers, and gravitational models of provider influence. Provider-to-population ratios are computed within bordered areas. They are good for gross comparisons of supply between geopolitical units or service areas, and are used by policy analysts to set minimal standards of local supply and to identify underserved areas (Connor et al., 1995; Council on Graduate Medical Education, 1998; Schonfeld et al., 1972). However, they ignore the classic problem of patient border crossing, which can be substantial for small geographies such as urban census tracts. Also, supply ratios are blind to variations in *accessibility* within bordered areas, and do not explicitly incorporate any measures of the distance dimension of access.

Distance to nearest provider may be a sufficient measure for rural areas with few provider choices (Fryer et al., 1999; Goodman et al., 1992), but it ignores the full array of provider locations common in urban settings. Thus, it ignores the *availability* dimension of access. Average distance to provider within a system, e.g. all providers in a city, is a combined measure of accessibility and availability (Dutt et al., 1986). Unfortunately, it over-weights the influence of peripheral providers who are usually not a practical option for patients living on the opposite side of the city.

"Gravity" models, initially developed for land use planning (Hansen, 1959),[1] are also a combined indicator of distance and availability, and can provide the most valid measures of spatial accessibility. Gravity models assess the potential spatial interaction between any population point and all service points within a reasonable distance. The general formula for gravity-based accessibility is

$$A_i = \sum_j \frac{P_j}{d_{ij}^b}.$$

A_i is spatial accessibility from population point i, which may be a personal residence or the centroid of an area of interest such as a census tract or city. P is service capacity at provider location j. It reflects the number of providers at that location and their combined capacity for healthcare provision. d is the distance between points i and j, and b is a gravity decay coefficient, sometimes referred to as the travel friction coefficient. b represents the difficulty associated with travel for any given time or distance. Accessibility improves as the number of provider points increases, the capacity at any provider location increases, the distance to provider decreases, or the travel friction decreases.

Computing A_i over a field of population points is a good way to study geographic variation in accessibility. However, there are two problems with A_i. One is that the value of the decay coefficient is often unknown (Talen and Anselin, 1998), particularly for health

[1] Ironically, Hansen's (1959) often cited study of early gravity work concerned residential development in our case city, Washington, DC.

services. Simple values of 1.0 or 2.0 can be used if one assumes that attractiveness decays at a constant rate with increasing distance (Joseph and Bantock, 1982). However, the shape of decay rate may be exponential or otherwise nonlinear, depending upon many factors, such as service type.

Another problem with A_i is that its scale is not intuitive. Healthcare workforce policy makers most commonly report spatial accessibility in easily understood provider-to-population ratios, despite the aforementioned difficulty of applying ratios to urban communities. A clever method of marrying the gravity and ratio methods was suggested by Guptill (1975). From physician point locations in the city of Detroit, he created a physician density layer to represent physician accessibility across the city. His density surface was essentially a derivative of classic gravity formulations. Guptill overlaid the physician density layer with neighborhood borders, which permitted the assignment of a physician availability value to each neighborhood. It was then a simple matter to estimate neighborhood physician-to-population ratios by dividing the community's estimated physician availability by neighborhood population. There was no concern for patient border crossing because the density calculation, often referred to as a "smoothing" process (Kafadar, 1996; McLafferty et al., 1999), allocated each physician's availability into all neighborhoods reasonably served by that physician. Our case study presents an updated approach that is free of the compromises that Guptill found necessary, given the computing resources and data available at the time. These compromises included elimination of some relevant medical specialties, grouping of nearby physicians into single locations, and geocoding physicians to cell centroids rather than actual street addresses in order to reduce computer processing time.

Methods

Overview

Using ArcView 8.3 software, we first created a continuous map layer representing the density of primary care providers for children (PCPCs). Density layers are made of small cells (e.g. one tenth mile square) covering the entire field of interest. The PCPC density value associated with each cell is an estimate of spatial accessibility from the cell's center.

Departing from Guptill, we also created a population density layer from census block group points. This layer had the same cell size and extent as the PCPC density layer. With ArcView "map algebra" it is a simple matter to create a mathematical combination of two such layers. In the combination, we divided each cell's PCPC density by its population density to obtain a layer of cells having provider-to-population ratio values. This layer of cell ratio values can clearly reveal how spatial accessibility to PCPCs varies across the city in units that are easily understood.[2]

Our final task was to overlay the ratio surface with census tract borders, and compute the mean cell ratio within each tract. This allowed us to test for variation in spatial accessibility across socioeconomic gradients, such as tract median income and percent of minority residents.

Data

We accessed American Medical Association and American Osteopathic Association (AMA/AOA) membership data, including office addresses, for physicians practicing in Washington, DC, and all surrounding Maryland and Virginia counties and municipalities. This ensured that our provider density layer would reflect the influence of physicians located well outside the city. Data were obtained from PracticeMatch, Inc., a physician placement firm that uses a variety of methods to achieve an address file that is described as 98% deliverable through the US Postal Service. Our records were limited to pediatricians, family practitioners and general practitioners who listed their primary activity as "direct patient care" or "resident". Administrators, researchers and others not primarily involved in patient care were excluded. Addresses were geocoded to longitude and latitude using standard ArcView utilities and by referencing the TIGER/line 2000 street files from the Census Bureau.

It is likely that some physicians who work or volunteer part-time in one of the city's safety-net community clinics might not list the clinic as a primary address. This could result in an under-estimate of PCPC accessibility in disadvantaged areas. We conducted a telephone survey of 24 community health clinics, identified by the city's Department of Health, to ascertain the level of physician availability in these settings. Response rate was poor, at 50%. Many of these clinics are poorly staffed, and some are ephemeral in nature. Some are primarily shelters that provide limited medical care, while others specialize in non-pediatric services, such as HIV care. The number of full-time physicians per responding clinic was low, ranging from <1.0 to 4.0.

The District of Columbia Primary Care Association (2002) conducted a similar survey and reported similar findings (2002). Unfortunately, neither survey was able to determine which community clinic physicians were

[2] Kafadar (1996) performed a similar operation with a disease density layer and a population layer. Her layers were combined in a different way for a different purpose—to discover areas of disease clustering.

primarily based in other settings. Nor was it possible to add the survey data to our analyses and debit the corresponding physician efforts from our primary data source, the AMA/AOA file. However, given that the majority of community clinics (15) are located in the most affluent quadrant of the city (Northwest), and that the physician effort is quite low in all of these settings, we have little concern for overreporting social disparity in PCPC accessibility.

The block group centroid data and census tract polygon files are bundled with ArcView by the vendor, ESRI, who obtained the data from the Census Bureau's 2000 Census and Tiger/line files.

Physician density

We used the ''Gaussian kernel'' method for creating a density layer. The computational details are beyond the scope of this paper, but the quadratic approximation formula used by ArcView Spatial Analyst are well described at the web site of Quantitative Decisions Inc. (2000).[3] Generally, each provider is represented on a map surface by a cone, centered at the provider's office location. Cone volume reflects the provider's total capacity for service, conveniently assumed to be 1.0. The radius of the cone base reflects what is believed to be the extent of the provider's practical service area. Provider capacity is allocated to the cells underlying the cone in such a way that cells near the cone center receive higher values of service capacity (i.e. accessibility), and those near the periphery of the cone receive very little. In other words, a cell's accessibility value is inversely related to its distance from the cone's center. The density values of all cells covered by the cone sum to 1.0.

Provider cones frequently overlap, either partially or fully, as in the case of physicians belonging to the same practice. Cells in these overlapping areas receive an accessibility score (density value) that is the sum of contributions from all overlying cones. As a measurement refinement, a given provider's cone volume need not be 1.0. It can be adjusted for any number of factors. We followed American Academy of Pediatric guidelines (2000) by weighting full time pediatricians who self-report as working primarily in patient care as 1.0, weighting pediatric specialists in patient care as 0.165, and weighting family practitioners and general practitioners as 0.25. The weights of all residents in training were further discounted by multiplying by a factor of 0.35.

Yet a vexing problem remains. What area should be used to model the reasonable service area of a typical provider? In other words, what radius should be used to define the base of each cone? (Gravity modelers face similar challenges.) If the goal is to model actual service area then a suitable radius can be empirically derived from patient visit records—a daunting task made more difficult by the recent implementation of the Health Insurance Portability and Accountability Act to protect patient confidentiality. However, our purpose is to explore issues of social equity. Therefore, we aim to model potential spatial accessibility, not actual access and utilization of healthcare.

We experimented with two radii, the first based on a study of primary care travel patterns from two predominantly African American Washington neighborhoods (Shannon et al., 1978). The study, though dated, tangentially provides a suggestion for the distance threshold beyond which the city's poor would find it difficult to maintain a consistent provider relationship. Poor residents of a neighborhood 4.9 miles from the closest charity care site found the distance to be insurmountable, while the poor of a neighborhood 2.9 miles from the same site used it frequently. Therefore, the midpoint of those distances, 3.9 miles, might be considered a reasonable radius for a primary care service cone in this city.

We also computed a density layer using a 3.0-mile service area radius. This value is based on our familiarity with the city's population, transportation difficulties, informal discussions with parents of patients visiting our pediatric care institution, and informal observations concerning continuity of care at our facility. The two radii, 3.0 and 3.9 miles, yielded very similar results. In the interest of space we report only the 3.0-mile radius results, recognizing that more research is required before incontrovertible conclusions about PCPC accessibility can be drawn.

Field cell size is another parameter for density calculations. We used one tenth-mile square as the cell size, which yields a smooth map resolution. However, the accuracy of density estimate for any given cell is questionable. This is not a major concern, as we are not performing analyses at the cell level. In the process of map inspections, such small cells are visually aggregated over neighborhoods. Also, the census tract statistical analyses described below are performed on the means of dozens of within-tract cell values. These aggregations ''average out'' the precision errors occurring at the cell level.[4]

Population density

Census block group centroids were the basis for creating the child population density layer. The purpose

[3] See Longley et al. (2001), McLafferty et al. (1999), and Silverman (1986) for thorough discussions and examples of kernel density estimation.

[4] See Longley et al. (2001) for an excellent discussion of uncertainty in spatial analyses.

here was not to model travel friction (i.e. distance decay), with its peaks and valleys, as this was accounted for in the PCPC density layer. Rather, the goal was to achieve a smooth layer representing density of fixed residential locations. This required a cone radius that would allocate a population of a block group point over the entire block group area, and also overlap with adjacent block groups enough to smooth out the centroid peak. We experimented with many radii and determined the 1.0 miles worked satisfactorily. The resulting surface layer was reasonably smooth and showed little or no population in large parks, bodies of water, and business and government centers. It should be noted that this radius might not be appropriate for all US urban areas.

Analyses

The PCPC density layer cells, in physician per square mile units, were divided by the spatially coincident population density layer cells, which were in child per square mile units. The resulting physician per child values were then multiplied by 100,000 to achieve a layer of cells values in units of physicians per 100,000 children. This is the scale that healthcare workforce policy makers most commonly work with.

Ten of the city's 188 census tracts were removed from further analysis because their population was below 200 persons. Low population areas have very unreliable ratio estimates because small changes in physician density, the numerator, result in wild fluctuations in estimated ratios. These were primarily federal or city government, or military areas.

We calculated the mean PCPC-to-child population ratio of all remaining cells. We also overlaid the ratio layer cells with census tract polygons, and used the ArcView "zonal statistics" function to calculate the mean ratio (i.e. mean spatial accessibility) for each tract. To quantify the social disparities we computed Spearman's correlations of tract spatial accessibility with tract median income and with the percentage of African American residents, the predominant minority in the city.

Results

Maps

The density maps in Figs. 1–3 show 5617 cells of one-tenth square mile size, which comprise 55.86 miles^2 and 178 census tracts. This excludes the aforementioned low population areas. However, physicians and children located in masked areas and adjacent jurisdictions do contribute to the density calculations and maps in the manner described in the methods section.

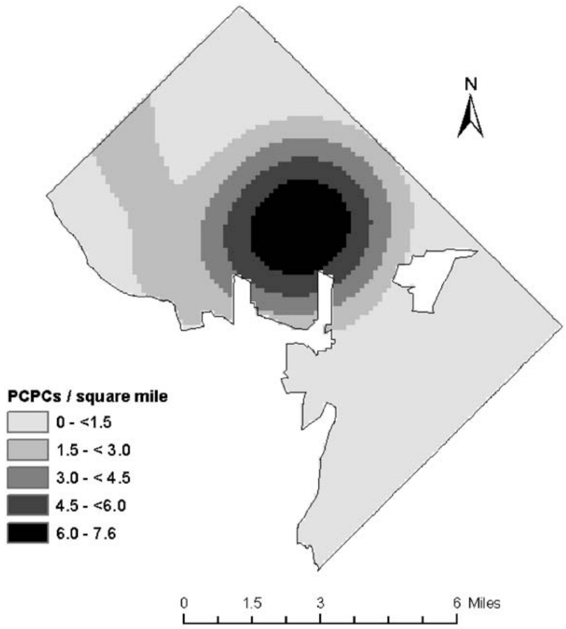

Fig. 1. Density of primary care physicians for children (PCPCs) per square mile.

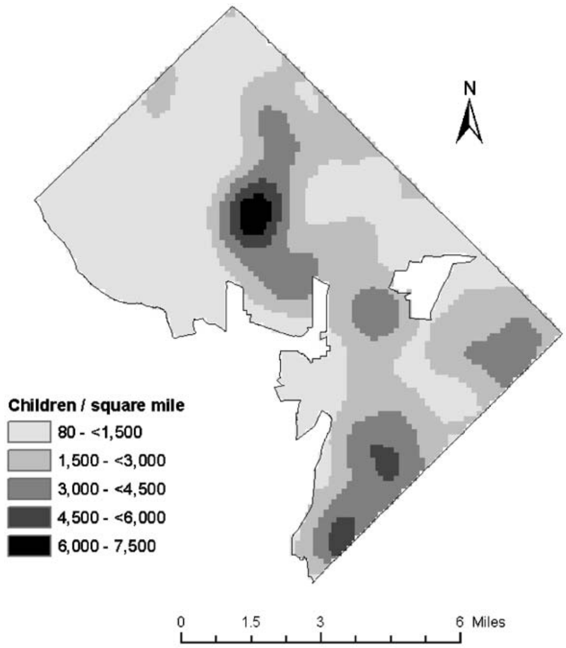

Fig. 2. Density of children per square mile.

Fig. 1 is the density of primary care physicians for children (PCPCs) per square mile. The dense central area represents the influence of the large number of pediatricians, pediatric specialists and pediatric residents

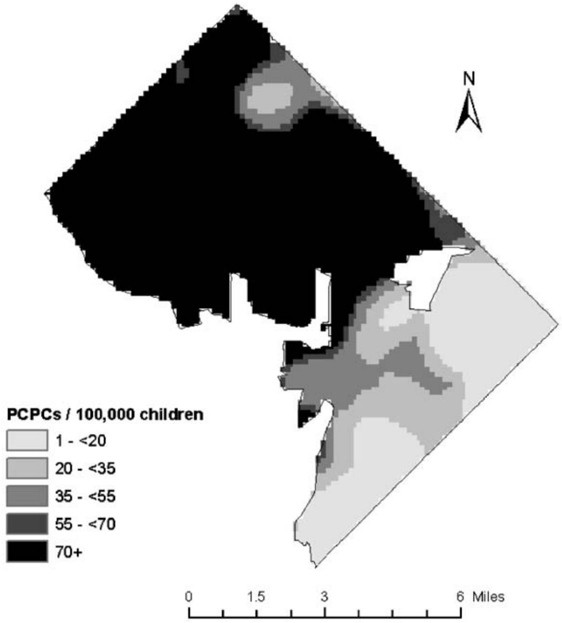

Fig. 3. Physician-to-child population ratios.

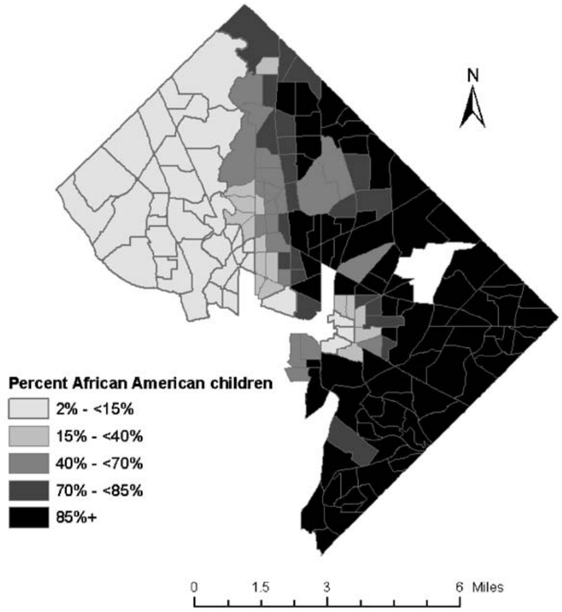

Fig. 4. Percent of children who is African American by census tract.

located at Children's National Medical Center (CNMC), a regional pediatric care and teaching facility.

Fig. 2 presents the density of the child population in the study area. The area of highest density is the neighborhood of Adams Morgan, just west of CNMC. This is a socially mixed area with a large proportion of Latino and African American families. All of the other higher density areas, including the north-south tails extending from Adams Morgan, are predominantly African American.

Fig. 3 presents the ratio of PCPCs per 100,000 children, our measure of spatial accessibility. This map is essentially Fig. 1 divided by Fig. 2, multiplied by 100,000. Most of the central and western parts of the city appear to have very high PCPC accessibility. This is a combined effect of CNMC's influence and the relatively low population density in the western part of the city. Areas of relatively poor accessibility include a pocket in the north, known as the Georgia Avenue corridor, and the southeastern third of the city.

Comparing Fig. 3 to maps of neighborhood socio-economic characteristics can reveal disparities in spatial accessibility. An example is Fig. 4, which displays census tracts shaded by percent of children who are African American. The extreme east-west racial segregation of Washington, DC is clear. The western third of the city is predominantly white, the eastern half is predominantly black, while Latinos are concentrated in the centrally located Adams Morgan community (dark area of Fig. 3, but not apparent in Fig. 4). Three observations emerge from a comparison of Figs. 3 and 4. First, the predominantly white western third of the city has ample accessibility to PCPCs. Second, CNMC provides ample accessibility for a large section of the city that includes children of all races and ethnicities. Third, the African American children living in the southeastern third of the city have relatively poor accessibility.

To conserve space, we do not present the map of census tract median income. It shows a pattern similar to the percentage of African American communities shown in Fig. 3, although the east-west gradient is less clear. The spatial correlation of race and income is imperfect, as there are African American communities with middle and upper incomes. This suggests that, for this city, there is greater racial than income disparity in spatial accessibility to PCPCs. In other words, the racial makeup of one's neighborhood is a greater risk factor for poor accessibility than is the income of one's neighborhood.

Statistics

The mean density of PCPCs, over all 5617 cells in the analysis area was 1.92 PCPCs per square mile. This is equivalent to a supply of approximately 107 full-time PCPCs for the city.[5] The child population of our analysis area was 112,910. Therefore, the citywide

[5] As explained earlier, this estimate includes the potential influence of PCPCs just outside the city.

supply (i.e. citywide accessibility) is 95.0 PCPCs per 100,000 children.

The Spearman's correlation over 178 census tracts between our accessibility measure (mean PCPC-to-population ratio) and percentage of African American children was –0.68 ($p<0.0001$). The correlation between the accessibility measure and median income was 0.44 ($p<0.0001$). These findings corroborate the conclusions from the maps. Lower accessibility is associated with lower neighborhood income and higher neighborhood percentage of black residents. Furthermore, neighborhood race appears to be more strongly associated with low accessibility than neighborhood income.

Discussion

Findings

The most effective and efficient PCPC-to-child population ratio is debatable. The American Academy of Pediatrics (2000) reviewed the only two available recommendations, 41.2 (Marder and Gaumer, 1991) and 49.2 (US Department of Health and Human Services, 1980) pediatricians per 100,000 children, and reported the actual nationwide ratio for 1998 as 57.5 pediatricians per 100,000 children. Our Washington, DC ratio of 95.0 PCPCs per 100,000 children is not directly comparable to these benchmarks because it includes, in addition to full-time pediatricians in patient care, the appropriately discounted contribution of general and family practitioners, pediatric specialists, and pediatric residents. To our knowledge, no recommendations exist for supply levels in these terms. However, the AAP reports the national average supply level for PCPCs to be 85.0 per 100,000 children. This is reasonably close to our finding of 95.0 for Washington, DC.

Clinical colleagues have suggested that the elevated PCPC level for our city, 10 per 100,000 higher than the nation, may be an artifact of the AMA survey methods, which are the basis for both our estimate and those of the AAP. Respondents are asked to indicate how the majority of their time is spent—clinical care, administration, research, teaching, etc. While virtually all clinical care respondents dedicate some time to non-clinical activities, the proportion of non-clinical time for full-time pediatricians at Children's National Medical Center (CNMC), a teaching institution, may be higher than the national average. Therefore we assume that the citywide supply level, i.e. average spatial accessibility, is approximately on par with the national average.

This finding is contrary to previous reports (American Academy of Pediatrics, 2000) and unpublished impressions of healthcare workforce experts with whom we have spoken, all suggesting an excessive overall supply level for the city. Whether the city's average spatial accessibility is on par or elevated, our results indicate that large areas of the city occupied by African American children are still underserved. To illustrate, make the conservative assumption that our PCPC enumeration is comparable to straightforward pediatrician enumerations used in the supply level recommendations. Further assume that the lower of the two recommendations, 41.2 per 100,000 (Marder and Gaumer, 1991), is sufficient. By this low benchmark Fig. 3 suggests that between one quarter and one third of the study area have substandard accessibility.

Nearly all of these areas are predominantly African American. This raises the possibility that racial residential segregation plays a role in disparity in PCPC spatial accessibility. Residential segregation creates minority communities that become isolated from municipal goods, economic and social opportunities (Wilson, 1987) and, apparently, health services. Racial segregation has been linked to higher mortality rates for African American infants (Polednak, 1996), minorities of New York City (Fang et al., 1998), and African-American men and women living in segregated areas in the US (Hart et al., 1998; Jackson et al., 2000). A study of general practitioners in Munich, Germany found that physicians appeared to avoid areas with high concentrations of immigrants and minorities (Shannon and Cutchin, 1994). Our data, which is cross-sectional in time and administrative in origin, cannot be used to infer motivations behind physician location, a complex issue considered by others (Costa et al., 1996; Ernst and Yett, 1984; Holmes and Miller, 1986; Mullan, 2002; Szafran et al., 2001). Whatever the driving forces, our data show that the results are remarkably unfair to minority and poor children. A survey of Washington families affirms a sense of unfairness regarding physician location (Dutton, 1986).

The disparities may be even worse if geographic variation in transportation options is considered. More options are generally considered to improve accessibility. For a given travel distance, those who are solely reliant on public transportation may face more travel friction in the form of time delays and higher costs, thus decreasing accessibility (Gesler and Meade, 1988; Shannon et al., 1973). While public transportation nodes are evenly distributed throughout the city, a map of percent of households owning vehicles (not shown) demonstrates that the African American neighborhoods with poor PCPC spatial accessibility (Fig. 3) have fewer transportation mode options.

It should be noted that, like many studies of spatial accessibility, our method only concerns *potential* spatial accessibility, not actual access or utilization of services.[6] Only complex and expensive investigations similar to

[6] See Khan (1992) for a thorough discussion of actual and potential access of healthcare services.

that of Gesler and Meade (1988) can reveal the absolute significance of spatial accessibility for utilization, or the relative importance of spatial accessibility vis a vis the other components of healthcare access: affordability, acceptability and accommodation. Planners and policy makers continue to devote a great deal of attention to removing these other barriers. We have shown that, for this city, elimination of non-spatial barriers will not eliminate all barriers for the socially disadvantaged.

Methodological contributions

Our use of the Gaussian kernel density approach to measuring spatial accessibility to primary care providers has a number of advantages. It is similar to classic gravity models in that it accounts for both availability and distance of multiple providers, and the measure is gradually discounted as distance increases. Like other gravity methods it also avoids the patient border-crossing conundrum. But unlike classic gravity models, our measure of spatial accessibility is in intuitive units that are comparable over many settings and areas of different size. For example mean accessibility measures for neighborhoods, cities, counties and states can be compared.

The federal government spends a considerable amount of money to rectify the problem of spatial accessibility to primary healthcare. For example, $125 million is spent annually on medical student loan repayments and field operations of the National Health Service Corps (Heinrich, 2001), which places physicians in officially designated health professional shortage areas (HPSAs). However, the system for identifying HPSAs is fraught with problems that the Department of Health and Human services has been trying to address for many years without success (US General Accounting Office, 1995). For example, there is a lack of precision. Entire cities are designated as a shortage area, although some neighborhoods are underserved and some are not. Maps similar to Fig. 3 can be used to precisely place government subsidized providers and facilities in the most needy communities. Another problem is that HPSAs are a one-designation-fits-all proposition. An area may qualify for HPSA designation based on underservice for children, but receive additional resources for the elderly, or vice versa. Stratifying analyses like ours for different demographic groups or different medical specialties can improve the efficiency and effectiveness of resource distribution.

Alternative methods

We have presented one variant of gravity modeling, although density analysis is not usually referred to in those terms. A potentially significant shortcoming of our method is that it only accounts for the supply side of the service question, with no adjustment for variation in demand for physician services. To illustrate, consider a case where a pediatrician is located 3 miles to the west of a community and another is located 3 miles to the east. The one to the west practices in a heavily populated area, while the one to the east in a lightly populated area. All else being equal, the latter is more accessible, having less demand for services. But by our formulation both pediatricians contribute equally to the target community's spatial accessibility measure.

Joseph and Bantock (1982), Knox (1978), and Luo and Wang (2003) have proposed gravity models that adjust potential physician availability according to size, i.e. potential demand, of their surrounding population. However, attempts to adjust for demand in this way can become circular. In the example above, the pediatrician to the west may be in a densely populated neighborhood having an overabundance of pediatricians. Hence, her effective availability may actually be greater than the pediatrician located in the lightly populated area to the east. Should we first adjust the demand on each physician by the supply surrounding that demand, and then calculate each physician's availability based on the adjusted demand? And why stop there? We recognize the weaknesses of spatial accessibility measures that are adjusted and unadjusted for demand, and we encourage others to consider solutions to the problem. Knox (1978) also recognized the importance of transportation mode alternatives in gravity modeling and included an adjustment for percentage of car-owning households in his study of healthcare accessibility in Scotland.

Straight-line or Euclidian distance, which is the basis for our density estimations, is by far the most popular proxy for "travel friction" in the health services literature, because it is easily computed from geocoded patient and provider locations. However, Euclidian distance may be an imperfect proxy for travel friction. Travel time and travel distance might be better, but these must be computed from transportation network data, a burdensome process that carries its own sources of error. Some authors report high correlations between Euclidian distance and travel distance (Fryer et al., 1999; Phibbs and Luft, 1995), while others favor time or travel distance over Euclidian distance (Luo and Wang, 2003; McGuirk and Porell, 1984; Shannon et al., 1973). We assume that using travel distance or travel time is moderately superior, and we are exploring the issue for our city's children.

Additional limitations

It must be recognized that not all primary care is delivered by physicians (Cooper et al., 1998). Nurse practitioners, and physician's assistants contribute a great deal of quality care to children (Hooker and McCaig, 2001). This would not affect our conclusions about variation or disparities in spatial accessibility if there were a high spatial correlation between physicians and these midlevel providers. Our impression is that the spatial correlation of these professional groups is quite high in the city, though we lack the data to demonstrate it. Washington, DC regulations require that registered nurses and physician assistants practice in the presence of a physician. Nurse practitioners are semi-autonomous. They do not require a physician on the premises. However, it is very impractical for them to set up autonomous practice sites because their services must be contracted under a collaborative arrangement with physicians, and it is difficult for them to obtain insurance reimbursements independently of physicians. Still, it is possible that the within-practice staff proportion of midlevel providers is higher in the areas we have identified as underserved. If so, then disparities in accessibility may be less than we have reported.

Some have argued that daily activity space, a potentially wide ranging area, is a better representation of a persons' location than either residence, or our residence surrogate, block group centroid (Cromley and Shannon, 1986; Gesler and Meade, 1988; Shannon and Spurlock, 1976). This is undoubtedly true for adults. However, its significance for children is limited, as a large proportion of their lives are spent at home or in neighborhood schools. Most parents prefer to use pediatric services close to home, for convenience and sense of security. Still, we recognize that all healthcare spatial accessibility measures, including ours, that rely on residential addresses may be less applicable to adults than to children.

Future directions

The previous discussion identifies several avenues for methodological improvement: the search for a satisfactory adjustment for demand on physician availability, an adjustment for travel mode options, assessment of the improvements achievable through use of travel time or travel distance, and collection and incorporation of data on midlevel and safety net providers.

It would also be worthwhile to conduct research to determine the most appropriate service radius to use in the creation of provider density layers. This would ideally be distance beyond which patients found it difficult to maintain a consistent relationship with the provider. The work by Shannon et al. (1978) suggests that our cone base radius, 3.0, is reasonable. However theirs is an older study and only concerned healthcare seeking behavior of two Washington, DC neighborhoods. A representative survey of city residents and an examination of medical records, indicating patient origin, adequacy of utilization and consistency of patient–provider relationship, could reveal a better radius. Also, given that burden of transportation probably varies with socioeconomic status and neighborhood characteristics, it might be that radius should vary with ecological circumstances.

Finally, the method for creating the population density layer could be improved. The smoothed cones of 1.0-mile radius applied to block group centroids may not be the best way to represent population density. This radius may be too large for the most highly congested areas, such as Adams Morgan, as it may spread the population effect into less populated adjacent areas. It is certainly too small for rural areas, where block group centroids are very sparse. Researchers should experiment with population density methods to determine what is best for their setting.

Summary

This paper demonstrates a method for measuring and analyzing spatial accessibility for primary care physicians for children (PCPCs) in an urban area—a common and persistent problem for minority neighborhoods. A surface of PCPC-to-population ratios is created from a density layer of PCPCs and a density layer of child population. Working with such a ratio layer has several advantages over other measures of spatially accessibility. It avoids the patient border-crossing conundrum, it provides good granularity for congested areas, it incorporates provider distance as well as provider supply, and it reports accessibility on an intuitive, standard scale used by healthcare workforce policy makers. We found that, while our city may have an elevated supply of PCPCs compared to the national average, large areas of predominantly African American residents fall far below the standards for PCPC accessibility.

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